Annual Report
Research Work Order 111
30 October 2004

Title:

Estimating detection probabilities for community assessment and population monitoring

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Abstract: Wildlife biologists traditionally rely on counts of animal diversity and abundance to inform management and conservation decisions. Uncertainty in the interpretation of these estimates arises when counts vary due to factors unrelated to animal abundance. For example, trends in long term counts of songbird populations may reflect long term changes in songbird populations, or they may reflect long term changes in observer's ability to hear the birds they are counting. If changes in the environment, such as increasing background noise or encroaching vegetation, reduce the chances an observer will hear individual birds (their detection probability), trends in count data will decline even though true population levels are stable. The goal of our research is to develop a better understanding of the factors affecting detection probabilities on count-based surveys, and better statistical methods for adjusting counts to correct for biases caused by differences in detection probabilities. We are using a combination of analytical and experimental approaches to understand and account for biases inherent in avian point count surveys which are widely used in research and environmental monitoring programs. Analytical approaches are developed from existing point count data collected in Great Smoky Mountains National Park. Experimental work is based on a system we have developed that uses a laptop

computer and a radio transmitter to control a set of player/speaker devices placed at known locations around a census point. The system allows us to realistically simulate a known population of songbirds, vary a range of factors that affect detection probabilities, and evaluate the performance of observers using various field and analytical methods. Our goal is to find new applications of theory and sampling methodologies that result in practical improvements in the quality of community assessment and animal population monitoring data.

Overview:

Assessment and monitoring of animal populations and communities is a common objective of state and federal conservation agencies interested in preserving biological diversity. Three metrics are widely used by ecologists in assessing animal communities and populations. These metrics are:

1. Abundance (population size or density) of a particular species.
2. Species richness
3. Proportion area occupied by a particular species.

Sound statistical estimates of these quantities are necessary to meet the objectives of most population monitoring programs. In this research work order we briefly discuss estimation for each of these metrics. We show how estimates of detection probabilities are often essential for making valid inferences about populations. We then suggest a range of research objectives that will be considered under the general umbrella of this research work order.

<u>1. Abundance</u>

There are many methods of estimating animal abundance for wild animals (Seber 1982). Count based methods are common for many taxa. Counts of animals are converted into population estimates by dividing the count by an estimate of the probability of detection of an individual animal (Lancia et al. 1994). Point counts (Ralph et al. 1995) are commonly used for birds, and we now focus on that method.

1.1 Point Counts

Point counts are widely used to estimate the abundance of bird populations (Ralph and Scott 1981; Ralph et al 1995). Data are easy to collect compared to more costly mark recapture methods. Typically point counts have been viewed as relative abundance indices, standardized protocols are emphasized to reduce sampling bias (Ralph et al. 1995). The weaknesses of this approach, and the importance of estimating detection probability have been noted for some time (see for example Ramsey and Scott 1979; Reynolds et al. 1980; Buckland et al. 1993) and emphasized recently (Nichols et al. 2000; Buckland et al. 2001; Farnsworth et al 2002). Two recent overview papers in the Auk by Thompson (2002) and Rosenstock et al. (2002) stress how important the estimation of detection probability is to making sound inferences from point counts.

Three approaches for estimating *p*, the probability of detection, can be found in the literature, and they all make different assumptions about the detection process. Double-observer approaches require that two observers detect birds simultaneously on the same sample area. Estimates are then derived using either a modified Lincoln-Petersen capture-recapture model based on the birds detected by both, one or the other, of two independent observers (Caugley and Grice 1982; Marsh and Sinclair 1989; Simons et al. unpublished bird counts) or a 2-sample removal model based on the number of birds detected by two dependent observers (Nichols et al. 2000). An alternative approach is the distance sampling approach (Emlen 1971; Ramsey and Scott 1979; Buckland et al. 2001). This approach assumes that detection is a decreasing function of distance and that nothing else influences detection. Analysis is simplified using the publicly available DISTANCE program (Buckland et al. 2001). A third alternative is to use the time of detection approach of Farnsworth et al. (2002), where each individual bird's first detection time is modeled using a removal modeling approach (Zippin 1958; Seber 1982).

We believe it is important to model the overall probability of detection of an individual bird as made up of an availability process (the probability of a bird being available for detection), and a detection process (the probability of a bird being detected, given that the bird is available for detection).

$$P\,[\text{bird detected}] = P\,[\text{bird available}] \;\; x \; P\,[\text{ bird detected} \mid \text{available}]$$

An advantage of using the time of detection method in combination with other methods is that it allows separate estimation of the probability of an animal being available, and the probability of an animal being detected given that it is available (Pollock et al. 2002).

1.2 Testing Point Count Methods

We are determined to move this work beyond theory and into the real world of monitoring bird populations. To do this we are planning to evaluate current and new sampling methods under simulated field conditions. We have developed a system for simulating census conditions when most birds are identified by sound, for example most BBS routes. The system uses a laptop computer and radio signals to control a set of player/speaker devices that can be placed at known locations around a census point. With the system we will be able to realistically simulate and quantify a known population of songbirds, vary a range of factors that affect detection probabilities, and then evaluate the performance of various field and analytical methods. We would also like to investigate the potential for using tablet computers to collect field data. In the near future these devices will make it feasible to automate some aspects of time and distance estimation, and reduce data transcription errors.

We anticipate that our analyses will provide field biologists and natural resource managers with a clearer understanding of the biases and precision of current sampling methods, and the improvements that would be expected if additional information needed to estimate detection probabilities is collected (various combinations of distance, multiple observers, and time of detection information).

Our goal is to find new applications of theory and sampling methodologies that will result in practical improvements in the quality of bird census data.

2. Species Richness

Estimating species richness (i.e., the actual number of species living in a given area) is a crucial component in animal community monitoring programs (Boulinier et al. 1998). Often count data (e.g., the total number of species recorded in a given area at a given time) are used as a ‘naive’ estimate of the species richness. For example, by electro- shocking a small portion of a stream, the number of different species of stream fish could be obtained. The problem is that some species may escape detection for various reasons, so that the estimate is severely negatively biased for the ‘true’ species richness for that section of the stream.

A large body of literature exists for estimating species richness. These models allow for uncertain detection of each species (Boulinier et al. 1998). Statistical methods adapted from capture-recapture and removal sampling, originally used to estimate individual species abundance can be applied here (see for example, Burnham and Overton 1979; Nichols and Conroy 1996; Boulinier et al. 1998). These methods have begun gradually to be used in the ecological literature, but progress has been slow, considering that the methodology has been around since 1979.

Ecological monitoring programs typically study changes in animal communities over many years. Recently, Nichols and various co-workers have noted that the capture-recapture methods, used to estimate species richness, can be extended to multiple time points, making it possible to estimate local extinction, recolonization, and turnover rates of species (Nichols et al. 1998a; 1998b; 2001).

The previous developments have assumed that species richness and community dynamics parameters could be calculated for a suite of species using only one sampling method. This may be reasonable for species that are easy to detect (e.g., birds in certain habitats may all have a positive probability of being detected buy sight or sound on point or transect counts). However, for other suites of species, such as mammals, there will be no one sampling method that could possibly detect all species. Small mammals may be detectable using one kind of trap, while larger mammals may be caught in different kinds of traps or detected by their sign. Very little research has been done on this problem. Community ecologists usually build up a species list using as variety of techniques and assume that it is complete. One possible approach might be to have several investigators each develop species lists using the same methods and then estimate species richness using a model that allowed heterogeneity and time variation. Another approach might be to try using one investigator at several close time points and again use a model that allowed heterogeneity and time variation.

All of the methods discussed previous describe estimation for a single patch of habitat (e.g., a park). Sometimes community ecologists desire estimates over a variety of spatial scales (e.g., park, series of parks, province etc.). These estimates are typically viewed as minimum estimates based on the assumption that species lists are known without error at all spatial scales. It is not clear how to estimate “true” species richness, or equivalently the number of species not detected in these complex systems.

3. Proportion of Area Occupied (PAO)

MacKenzie et al. (2002) describe an approach for estimating the proportion of sites occupied by a species of interest. They envision a sampling method that involves multiple visits to sites at which a species might be detected. Although surveys are conducted during a season when the species might be detected, a species may go undetected even when present. Sites may represent discrete habitat patches in a metapopulation context, or sampling units (e.g., quadrats) regularly visited as part of a large-scale monitoring program. The patterns of detection and nondetection over the multiple visits for each site permit estimation of detection probabilities and the parameter of interest, proportion of area occupied (PAO).

The proportion of area occupied method of MacKenzie et al (2002) is closely related to closed capture-recapture models and it properly takes account of the fact that the species may not be detected with certainty at each site. Thus naïve estimates of proportion of area occupied would have a serious negative bias. Even more importantly this bias would be likely to vary over time and space because species detection probabilities are not likely to be constant.

The methods proposed here to estimate the proportion of sites (or more generally, the proportion of sampled area) occupied by a species can be implemented more easily and less expensively than the methods used for estimating abundance. For this reason, the PAO method should be useful for large-scale monitoring programs. PAO estimates may also be useful for the study of metapopulation dynamics. The proportion of patches occupied is viewed as a state variable in various metapopulation models (e.g., Levins 1969, 1970; Hanski 1992, 1994, 1997; Lande 1987, 1988).

Proportion of area occupied methods can be extended in various ways. There will certainly be heterogeneity caused by differences in local species abundance among sites. This can be handled using the Norris and Pollock (1995,1996) and Pledger (2000) finite mixture approaches similar to for capture-recapture models. In addition, the utility of using multiple observers on multiple visits has not been explored. This turns out to be a special case of the robust design (Pollock 1982) that enables one to separate out the probability of a species being available for detection from the probability of the species being detected given that it is available. These models are related to the work of Kendall and Nichols (1995) and Kendall et al. (1997) on temporary emigration). Theoretically this approach could be used if there was concern that a species may not be available for detection during each visit to a site. It might also be used on a longer time scale to look at local extinction and re-colonization processes

Objectives:

1. We will establish criteria for deciding when abundance, species richness, and proportion of area occupied metrics are appropriate.

2. We will use data from field experiments of simulated point counts and existing bird point count data from Great Smoky Mountains National Park to address specific objectives outlined below.

Point Count Objectives

New Methods

1. Review current methods in detail identifying the assumptions made by each one and showing how they influence the detection model.

2. Develop likelihood-based estimation of detectability parameters for distance, multiple observers, time of detection, and combined methods.

3. Develop multiple species analyses with common parameters so that rare species are not simply ignored.

4. Develop guidance for field biologists who use point counts in the form of both written descriptions of protocols for application of methods and a monograph where we present theory, some examples and simulations to illustrate the methodology in detail.

Test Methods Using the Simulation System

1. Develop the simulation system so that it can be used in the field to realistically simulate bird point counts.

2. Use data from the field experiments to test the assumptions and evaluate the costs and benefits of the different point count methods (distance, multiple observers, time of detection) described previously.

Species Richness Objectives

1. Develop refinements to methods to account for temporal changes in species richness.

2. Investigate species richness estimation for multiple sampling methods.

3. Investigate species richness estimation for multiple spatial scales.

4. Develop guidance for field biologists who use species richness estimation in the form of application protocols and publications.

Proportion of Area Occupied Objectives

1. Develop estimation methods for temporal changes in PAO.

2. Develop an extension of the estimation method to account for heterogeneity of detection.

3. Develop a new model that incorporates multiple observers and multiple visits to sites.

4. Develop guidance for field biologists who use PAO estimation in the form of application protocols and publications.

References:

Boulinier, T., Nichols, J. D., Sauer, J. R., Hines, J. E., and Pollock, K. H. (1998a). Estimating species richness: the importance of heterogeneity in species detectability. *Ecology* 79, 1018-1028.

Burnham, K. P., and Overton, W. S. (1979). Robust estimation of population size when capture probabilities vary among animals, *Ecology*, 60, 927-936.

Buckland , S.T., Anderson, D. R., Burnham, K. P., and Laake, J. L.(1993). Distance Sampling : Estimating Abundance of Biological Populations. Chapman and Hall, London.

Buckland, S.T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. (2001). Introduction to Distance Sampling. Oxford University Press, Oxford.

Caughley, G. and Grice, D. (1982). A correction factor for counting emus from the air, and its application to counts in Western Australia. Aust. Wildl. Res. 9, 253-259.

Emlen, J. T. (1971). Population densities of birds derived from transect counts. Auk, 88, 323-342.

Farnsworth, G., Pollock, K.H., Nichols, J. D., Simons, T. R., Hines, J. E., and Sauer, J. R. (2002). A removal model for estimating the detection probability during point counts divided into time intervals. *The Auk* 119, 000-000.

Hanski, I. 1992. Inferences from ecological incidence functions. American Naturalist 139:657-662.

Hanski, I. 1994. A practical model of metapopulation dynamics. Journal of Animal Ecology 63:151-162.

Hanski, I. 1997. Metapopulation dynamics: from concepts and observations to predictive models. Pages 69-91 *in* I. A. Hanski and M. E. Gilpin, eds. Metapopulation biology: ecology, genetics, and evolution. Academic Press, New York.

Kendall, W. L., and Nichols, J. D.(1995). On the use of secondary capture-recapture samples to estimate temporary emigration and breeding proportions. *Journal of Applied Statistics* 22**,** 751-762.

Kendall, W. L. , Nichols, J. D. and Hines. J. E. (1997). Estimating temporary emigration using capture-recapture data with Pollock's robust design. *Ecology* , 78, 563-578.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. Bookhout, ed. Research and management techniques for wildlife and habitats. The Wildlfie Society, Bethesda, Maryland.

Lande, R. 1987. Extinction thresholds in demographic models of territorial populations. American Naturalist 130:624-635.

Lande, R. 1988. Demographic models of the northern spotted owl (*Strix occidentalis caurina*). Oecologia 75:601-607.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15:237-240.

Levins, R. 1970. Extinction. Pages 77-107 *in* M. Gerstenhaber , ed. Some mathematical questions in biology. Vol. II. American Mathematical Society, Providence, R.I.

MacKenzie, D.I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and

C. A. Langtimm (2002). Estimating site occupancy when detection probabilities are less than one. Ecology (In Press).

Marsh, H. and Sinclair, D. F. (1989) Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. J. Wildlife Manage. 53, 1017-24.

Nichols, J. D., and Conroy, M. C. (1996). Estimation of species richness. Pages 227-234 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, D. C.

Nichols, J. D., Boulinier, T., Hines, J. E., Pollock, K. H. and Sauer, J. R. (1998a). Estimating rates of local species extinction, colonization and turnover in animal communities. *Ecological Application*. 8, 1213-1225.

Nichols, J. D., Boulinier, T., Hines, J. E., Pollock, K. H. and Sauer, J. R. (1998b). Inference methods for spatial variation in species richness and community composition when not all species are detected. *Conservation Biology*. 12, 1390-1398.

Nichols, J. D., Hines, J. E., Sauer, J. R., Fallon, F. W., Fallon, J. W., and Heglund, P. J. (2000). A double observer approach for estimating detection probability and abundance from point counts. The Auk, 117, 393-408.

Nichols, J. D., J. R. Sauer, J. E. Hines, T. Boulinier, and K. H. Pollock. (2001). Estimation of species richness and parameters reflecting community dynamics using data from ecological monitoring programs. Pages 181-187 in Glenn D. Therres, editor. Conservation of Biological Diversity: A Key to the Restoration of the Chesapeake Bay Ecosystem and Beyond, Conference Proceedings. Maryland Department of Natural Resources, Annapolis. 344 pp.

Norris, J. L., and Pollock, K. H. (1995). Capture-recapture model M_{bh}: Bivariate MLE of capture-recapture distribution and resulting model selection. *Journal of Environmental and Ecological Statistics* 2, 305-313.

Norris, J. L., and Pollock, K. H. (1996). Nonparametric maximum likelihood estimators for population size under two closed capture-recapture models with heterogeneity. *Biometrics* 52, 639-649.

Pledger, S. (2000). Unified Maximum Likelihood Estimates for Closed Capture-Recapture Models Using Mixtures, *Biometrics*, 56, 443-450..

Pollock, K. H. (1982). A capture-recapture design robust to unequal probability of capture. *Journal of Wildlife Management* 46, 752-757.

Pollock ,K. H., Nichols, J. D., Simons, T.R., Farnsworth, G.L., Bailey, L.L., and Sauer, J.R. (2002). The design of large scale wildlife monitoring studies. Environmetrics 13, 105-119.

Pollock, K. H., Nichols, J. D., Simons T. R., Farnsworth, G. L., Sauer, J. R., and Alldredge, M. (2002). Modeling availability and perception processes for detection in point counts of bird populations. Manuscript in Preparation.

Ralph, C. J., and Scott, J. M. (1981). Estimating Numbers of Terrestrial Birds.Studies in Avian Biology 6. The Cooper Ornithological Society.

Ralph, C. J., Sauer, J. R., and Droege, S. (1995). Monitoring bird populations by point counts. U.S. Department of Agriculture, Forest Service General Technical Report PSW-149, Albany.

Ramsey, F. L., and Scott, J. M. (1979). Estimating population densities with variable circular plot surveys. Pages 155-181 in Sampling Biological Populations (R. M. Cormack, G. P. Patil, and D. S. Robson, Eds). International Co-operative Publishing House, Fairland, Maryland.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. (1980). A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Rosenstock, S. S., Anderson, D. R., Giesen, K. M., Leukering, T., and Carter, M. F. (2002). Landbird counting techniques: current practices and an alternative. The Auk119: 46-53.

Scott, J. M., and F. L. Ramsey. 1981. Effect of abundant species on the ability of observers to make accurate counts of birds. Auk 98:610-613.

Seber, G. A. F. (1982), *The Estimation of Animal Abundance and Related Parameters* (2nd ed.), London: Charles W. Griffin.

Thompson, W. L. (2002). Towards reliable bird surveys: accounting for individuals present but not detected. The Auk119: 18-25.

Zippin, C. (1958). The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Prior year's report:

Accomplishments

Partial funding to begin this research was secured in August 2002 through Patuxent Wildlife Research Center (PWRC). Funding in the amount of $40,000 was provided by the USGS/BRD National Park Monitoring Project through Paul Geissler, and $22,000 was provided by the PWRC/U.S. Forest Service though John Sauer. The funding was obligated at North Carolina State University under a Research Work Order (#111) entitled "Estimating detection probabilities for community assessment and population monitoring" (Appendix A). A second increment of funding totaling $109,000 was obligated through RWO #111 in August 2003. This funding included $54,000 from the USGS/BRD National Park Monitoring Program through Paul Geissler, $20,000 from the PWRC/U.S. Forest Service through John Sauer, and $35,000 from PWRC through Jim Nichols. A third increment of funding totaling $60,000 was obligated through RWO #111 in July 2004. This funding included $53,000 from the USGS/BRD National Park Monitoring Program through Paul Geissler, and $7,000 from the USFWS.

Since establishing the Research Work Order in September 2002, a Ph.D. graduate student in the NCSU Biomathematics Program, Mat Alldredge, has been assigned to the project, development of a second generation simulation system has been completed, and the equipment and software interfaces necessary for the field experiments have been built. Mat Alldredge completed his Ph.D. in August 2004 and has continued on as post doc. New funding from PWRC obligated in August 2003 has been used to hire a second research associate, Ray Webster, a Ph.D. student in the NCSU Department of Statistics. Ray has begun to address the Species Richness and Proportion Area Occupied objectives of this research.

Specific accomplishments in FY04:

The focus of our efforts for the last year have been on the development and refinement of statistical methods for estimating abundance from point count data and on the development and testing of a simulation system for evaluating point count methods.

- Methods for estimating abundance

We have prepared four method papers for estimating the abundance of bird populations from point count data. Two of these papers generalize existing methods in an attempt to account for additional sources of variation and provide more precise estimates of detection probabilities and population size. Both of these papers have been submitted. The next paper presents a multiple species modeling approach for point count data using existing point count methodologies. The multiple species approach will give more precise estimates and may enable estimation of detection probabilities for rare species. The final paper is focused on estimating the probability that a bird is available for detection during a point count or the probability that a bird actually sings during the count. This is a source of bias that is often overlooked in surveys that may lead to underestimation of abundance. The objectives, results and status of the papers are:

Estimating detection probabilities from multiple observer point counts. In review: Auk

Objectives:

1. Present and illustrate the two independent observer method and potential models for estimating detection probability, including the use of detection distance covariates, showing that the models are essentially closed capture-recapture models.
2. Present and illustrate a more general model using four independent observers showing that multiple observer models are essentially

closed capture-recapture models that allow for individual heterogeneity.
3. Compare the efficiency of the two independent observer approach to the primary-secondary observer approach of Nichols et al. (2002).
4. Simulate data under a heterogeneous model to illustrate the levels of heterogeneity typically present in data and the effect of heterogeneity on two-observer models and index counts.

Implications and Findings

1. The independent observer approach gives more efficient (smaller variance) estimates than the primary-secondary observer approach.
2. Two-independent observer models appear to work well in practice and give reasonably precise estimates.
3. Four-independent observer model estimates indicate a negative bias in the two-independent observer model estimates.
4. Individual heterogeneity in detection probabilities is important, can be extreme and leads to negative bias in abundance estimates when models fail to account for it.

Time of detection method for estimating abundance from point count surveys. In review: Auk

Objectives:

1. Present a time of detection approach using a capture-recapture framework based on all detections of an individual as a more general alternative to the removal approach presented by Farnsworth et al. (2002).
2. Discuss field methods required to collect data suitable for this method.
3. Present a finite-mixture model for individual unobservable heterogeneity and a covariate model for observable heterogeneity.
4. Illustrate our methods with an example for three-unequal interval point counts and another for a four-equal interval point count survey.

Implications and Findings:

1. The time of removal method (Farnsworth et al. 2002) is a special case of the time of detection method.
2. Using the full detection history in a capture-recapture framework is more efficient (smaller variance) than the time of removal approach using only first detections.
3. Time effects can be an important source of variation in point count surveys, which cannot be modeled with the removal method.
4. Individual heterogeneity is important and leads to negative bias in abundance estimates when models fail to account for it.
5. Modeling the detection process is important to estimate abundance but the contribution of the availability component and detection given availability to the overall probability of detection is unknown.

Multiple species analysis of point count data: a more parsimonious modeling framework. Submission pending: Ecology.

Objectives:

1. Present a multiple species modeling framework to achieve more parsimonious models and explore its potential applications to three methods (distance sampling, time of detection and multiple observer) of analyzing point count data.
2. Discuss the importance of defining species groups and describe characteristics that can be used to define these groups.
3. Provide examples of grouping species and an analysis for each point count method using these species groups.

Implications and Findings:

1. Defining species groups based on similarities in the detection process is critical to multiple species modeling because this leads to a biologically reasonable set of *a priori* candidate models.
2. Using categorical variables or subjective rankings to define species groups is possible but may lead to poorly defined species groups as not all observers agree on the rankings for certain species.
3. Multiple species modeling with the distance sampling approach did not provide better estimates than a single species approach in my examples. Further investigation of distance models of multiple species data is necessary.
4. Multiple species models for the multiple-observer and time of detection methods did provide better estimates (more precise) than a single species approach.
5. Accounting for individual heterogeneity in detection probabilities is important in multiple species models. Failure to account for this leads to serious negative bias in abundance estimates.
6. This approach can be extended to modeling rare or uncommon species that typically cannot be modeled using a single species approach because of insufficient data. Additive species effect models will be particular useful in this respect.

Modeling the availability process for point count surveys using auxiliary data. Submission pending. Journal of Wildlife Management.

Objectives:

1. Investigate models for estimating the probability of a bird being available for detection in relation to singing rates or times using data collected separately from point count surveys. These estimates can be applied to any point count method to adjust for the proportion of birds that are unavailable during the point count survey.
2. Present a homogeneous Poisson singing rate model as a simple case for modeling the availability process.

3. Present finite-mixture Poisson models as biologically reasonable models for the availability process associated with differences in singing rates relative to breeding phenology of an individual.
4. Discuss “size” bias that may occur in the data and how to correct for this.
5. Present a nonparametric approach that uses the actual singing times of an individual, corrects for “size” bias in the data and then estimates the availability probability and variances by re-sampling the singing time data.
6. Present an example of the singing rate models using data collect on the Ovenbird and present an example of the singing time approach using simulated data.

Implications and Findings:

1. Homogeneous Poisson and finite Poisson mixture models can be fit to singing rate data using a maximum likelihood approach.
2. Obtaining maximum likelihood estimates for the three-point Poisson mixture model was problematic for our data.
3. The two-point Poisson mixture model fits the data reasonably well and gives reasonable estimates of availability probabilities. Changes in singing rate associated with breeding/nesting stage provide biological justification for the use of mixture models.
4. Individual heterogeneity in singing rates is important to model when estimating the probability a bird sings during a point count. Failure to account for individual heterogeneity in singing rates will lead to a positive bias in availability probability estimates or a negative bias in abundance estimates.
5. The nonparametric approach using singing time data also seems to work well based on simulation. The singing time approach is robust to nonrandom singing behavior and will generally be more applicable to estimating the availability process.
6. This approach works with all point count survey methods which allows for “snapshot” type approaches when movement is thought to be a problem in point counts.

- Simulation system for point counts

Simulation system hardware

A second generation simulation system has been completed and tested (Figure 1). The production of 32 remote receiver/speaker units is complete and 12 additional players are under construction. The system consists of a laptop PC play list generator attached via a serial port to a radio frequency transmitter that controls up to 64 individually addressable receivers (Figure 2). There are no practical constraints on the rates at which receivers can be addressed or the number of receivers that can be played simultaneously. The system will have a minimum range of 500 m, storage capacity of a minimum of 100 individually selectable high fidelity digitized songs, a minimum broadcast volume of 95 dB at 1 m, and will be capable of operating on battery power for a minimum of three hours. In FY04 we modified the players to allow us to use external speakers. We are now able to fix speakers in trees at heights up to 50 feet. This capability significantly improved the realism of our simulated point counts.

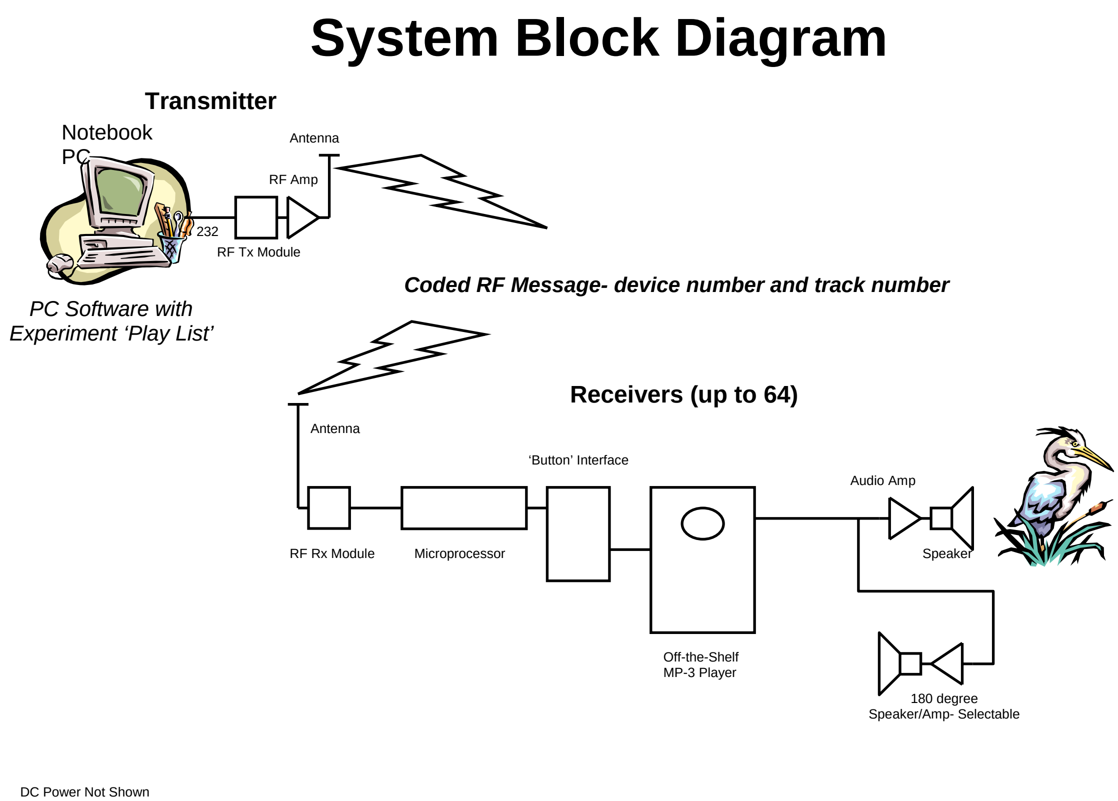

Figure 1. Block diagram of simulation system.

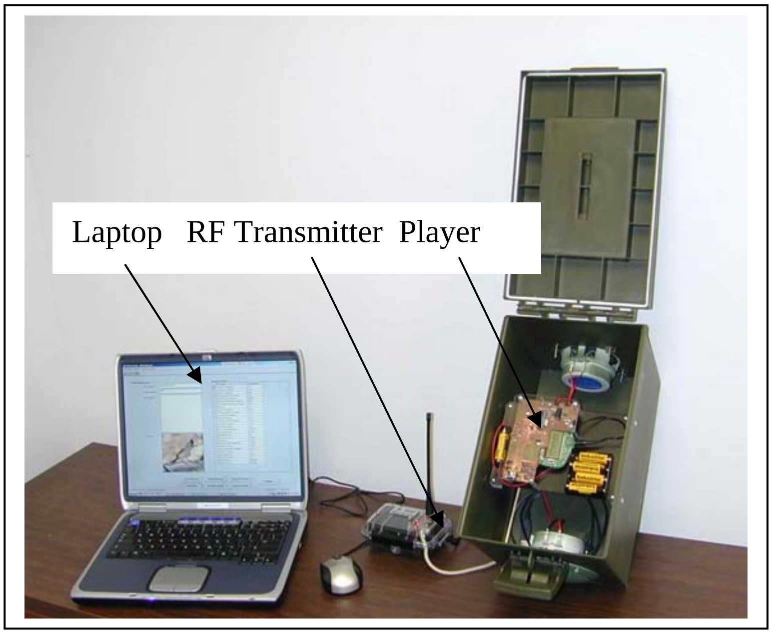

Figure 2. Production version of point count simulation system.

We have also modified our software so that singing rates can more accurately represent real birds during our simulation. This has been accomplished by using longer tracks with maximum singing rates and play/pause features on the players. This software upgrade is in its final stages and will be implemented in future experiments. Our goal is to have the complete simulation system built and tested by November 2004.

Our first experiments in November and December of 2003 and in March of 2004 were conducted in an open field (Figure 3).

Figure 3. December 2003 field experiments.

These experiments have provided some useful insights about point count surveys. It was immediately evident that observers were having difficulty localizing sound. This made matching the birds detected by observers to the location of the player more difficult than we expected. We used five species for these initial experiments. The five key species were Black and White Warbler, Black-throated Blue Warbler, Hooded Warbler, Ovenbird, and Wood Thrush.

Results from the March 2004 experiments indicate that observers tend to undercount birds (10 out of 15 observers undercounted). The percentage of the total birds counted ranged from 81% to 132% (Figure 4). Counts of Black and White Warblers underestimated the true value the most. This was not unexpected because of the species' high thin call and low singing rate.

When asked to estimate birds within a 50 m radius, observers tended to overestimate the number of birds (Figure 5). The true number of birds within 50 m shown in Figure 5 was 55 birds. Observers overestimated this by between 5 to 66 birds.

We were able to match 76.8% (1144 birds) from the March experiment to player locations which allowed us to estimate errors in distance estimation. Observers generally underestimated the distances to birds that were more than 30 m away (Figure 6). Observers tended to overestimate the distances to birds closer than 30 meters. The error in distance estimation across all distance was -20.0 m and tended to increase with increasing distance from the point (Table 1). Estimation errors exceeded 100 m for some observations.

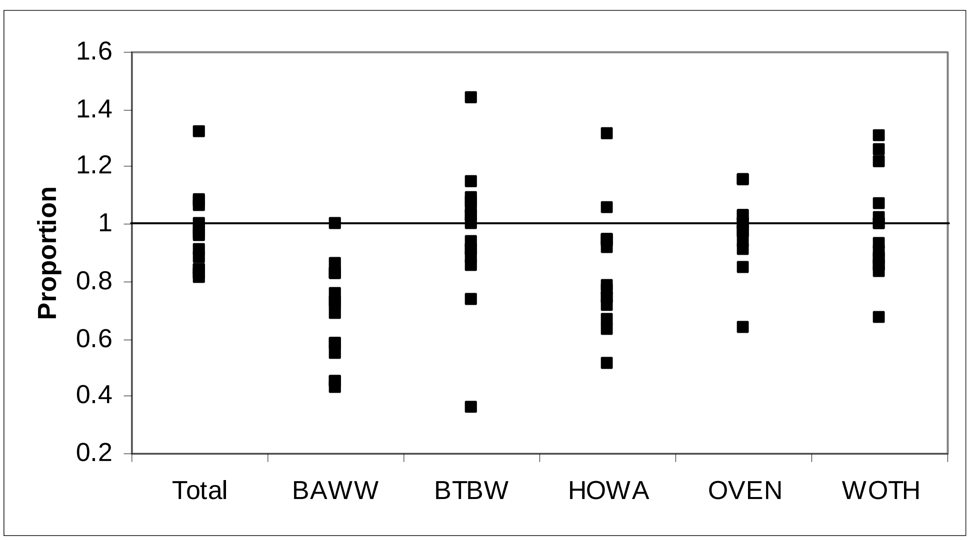

Figure 4. Proportion of total birds counted and proportion of birds counted for five key species.

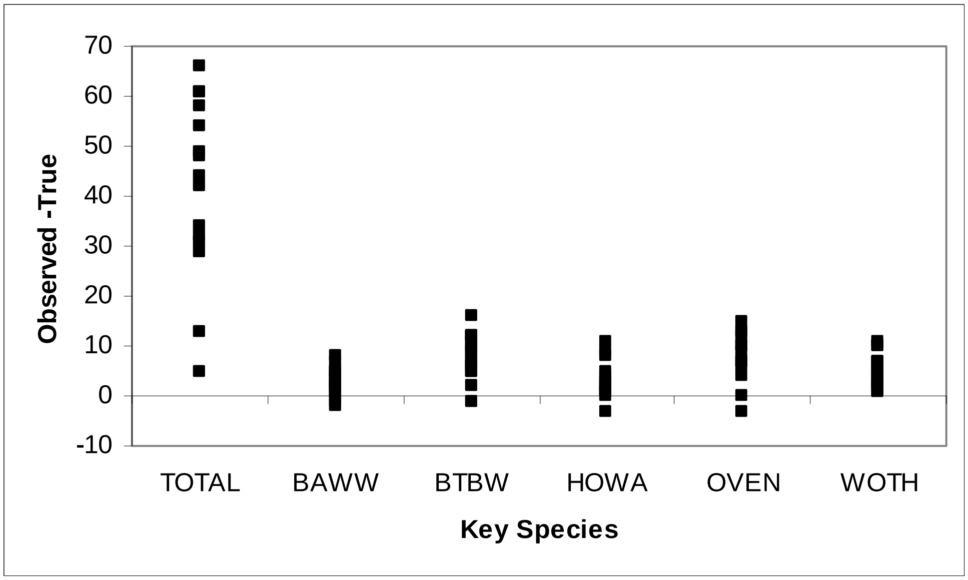

Figure 5. Difference between detected birds and the true number of birds within 50 meters across all birds and for the five key species.

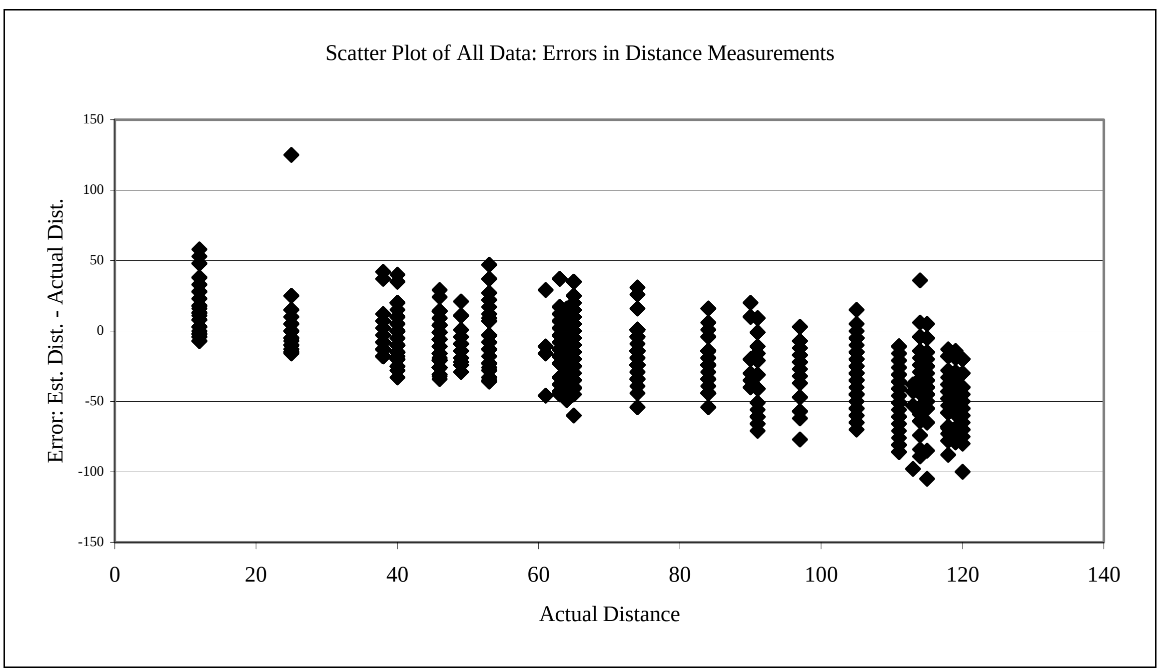

Figure 6. Error in distance estimates relative to the actual distance for ten point counts using 15 observers. Represents 1,144 distance estimates.

Table 1. Distance estimation error for point counts simulated in March 2004. Ten points and 15 observers were used, providing a total of 1,144 birds observed and matched to their true location.

	Avg. Error (m)	Std. Dev.	Max. Under-estimate	Max. Over-estimate	25th Percentile	75th Percentile
All Distances	-20.0	25.6	-105	125	-36	-4
Within 50 m	-2.1	17.7	-34	125	-13	5
50-100 m	-14.9	20.8	-77	47	-27	-3
Over 100 m	-41.7	20.9	-105	36	-55	-55

- Future directions

We are currently working on a methods paper that will describe the bird radio simulation system in detail, present some preliminary findings, and provide a reference for all future work.

Experiments during the fall of 2004 will be aimed at demonstrating how sources of variation commonly encountered in point counts introduce bias in the counts and confound spatial and temporal comparisons. We will look at ambient noise, singing rate, habitats, and observers as factors that often cause bias in point counts. These types of bias, present in all point count surveys, can cause apparent trends in data that are actually caused by changes in the detection process. Our goal is to find new applications of theory and sampling methodologies that result in practical improvements in the quality of community assessment and animal population monitoring data.

Our next objective is to compare the performance of distance, time of detection, and multiple observer methods of estimating detection probabilities on point count surveys. We will also evaluate violations of model assumptions in the application of these methods. Our goal is to provide guidelines for applying these methods more effectively, and to suggest preferred methods for various situations and objectives. These experiments will be conducted in the spring of 2005.

Other objectives that we hope to address over the next year include experiments to understand the extent to which observer performance can be improved through training. These experiments will include training in distance estimation which is likely the most difficult skill required on point count surveys. Other experiments will include detailed assessments of habitat effects, song characteristics, and singing rates on detection probabilities.

Public Interest Highlights:

Dr. Simons presented the keynote address to the Northeastern U.S. Partners in Flight conference in Blacksburg, VA in March 2003 entitled “Research on southern Appalachian forest songbirds; methods, models, and emerging issues.” The talk emphasized the importance of incorporating estimates of detection probabilities in abundance estimation, and the on-going research supported by this Research Work Order.

Dr. Simons also attended the National Park Service national inventory and monitoring conference in Washington D.C. in August 2003 and presented a poster entitled “Death, Taxes, and Point Counts: Is it worth estimating detection probabilities.”

Dr. Simons presented an invited seminar at Duke University in September 2004 entitled . “The importance of estimating detection probabilities in animal sampling.”

Dr. Pollock presented two invited papers at recent professional meetings:

K.H. Pollock. 2003. Modeling components of the detection process when sampling animal populations: Area, availability and perception components. The Wildlife Society, Burlington, Vermont.

K.H. Pollock, M.W. Alldredge, T.R. Simons. 2004. Application of capture-recapture type models in point count surveys. The Statistical Society of Canada, Montreal, Canada.

Publications:

Pollock, K.H., J.D. Nichols, T.R. Simons, G.L. Farnsworth, L.L. Bailey, and J.R. Sauer. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. Environmetrics 13: 105-119.

Farnsworth, G. L., K. H. Pollock, J. L. Nichols, T. R. Simons, J. E. Hines, and J. R. Sauer. 2002. A removal model for estimating detection probabilities from point count surveys. The Auk 119: 414-425.

Pollock, K.H., H.H. Marsh, L.L. Bailey, G.L. Farnsworth, T.R. Simons, and M.W. Alldredge. 2004. Methodology for separating components of detection probability in population abundance estimation: An overview with diverse examples. In Sampling rare or elusive species: Concepts, designs, and techniques for estimating population parameters. William Thompson (ed.). Island Press.

Alldredge, M.W. 2004. Avian Point Count Surveys: Estimating Components of the Detection Process. Ph.D. Dissertation, North Carolina State University.

Alldredge, M.W., K.H. Pollock, and T.R. Simons. (In review). Estimating detection probabilities from multiple observer point counts. The Auk.

Alldredge, M.W., K.H. Pollock, T.R. Simons, and J. Collazo. (In review). Time of detection method for estimating abundance from point count surveys. The Auk.

Alldredge, M.W., K.H. Pollock, and T.R. Simons. (In review). Multiple species analysis of point count data: A more parsimonious modeling framework. Ecology.

Alldredge, M.W., K.H. Pollock, and T.R. Simons. (In preparation). Modeling the availability process for point count surveys using auxiliary data. Journal of Wildlife Management.

Presentations:

M.W. Alldredge, K.H. Pollock, T.R. Simons, and J.A. Collazo. 2004. Multiple-observer and time of detection methods for estimating abundance of birds from point count surveys. American Ornithologists' Union in conjunction with the Society of Canadian Ornithologists. Quebec, Canada.

M.W. Alldredge, K.H. Pollock, and T.R. Simons. 2004. Multiple species modeling of point count surveys. American Ornithologists' Union in conjunction with the Society of Canadian Ornithologists. Quebec, Canada.

T.R. Simons, K.H. Pollock, and M.W. Alldredge. 2004. Experimental analysis of detection probabilities on avian point count censuses. Ecological Society of America Annual Meeting, Portland, Oregon.

Budget:

Current funding obligated under this Research Work Order is $229,000, representing approximately 67% of the total funding requested (Appendix A). These funds have been carried over under the Research Work Order which will remain in effect until 12/31/2007. To date funds have been used to provide salary support to Mat Alldredge through a research assistantship, to purchase supplies and equipment for the simulation system, provide hourly salary support for NCSU engineering students who are building the simulation system, and to provide a stipend for a second RA, Ray Webster, who joined the project in June 2004.

Next year's proposal:

<u>Need</u>

The objectives of this research have not changed from those described above, and in Appendix A. Results will provide better methods for the count based surveys that serve as the basis for most natural resource monitoring programs on NPS and other lands. Examples include vertebrate inventory and monitoring programs in National Parks and larger scale monitoring programs such as the Breeding Bird Survey.

Procedures/methods

See above.

Expected results or products

See above.

Technology/information transfer

Intended users of the products of this research are natural resource management practitioners. Products will be provided as protocols for survey and sampling methods that incorporate estimates of detection probability, and an assessment of the relative costs and benefits of alternative methods.

Work schedule and budget

Funding currently available will allow us to continue to address the objectives related to abundance estimation outlined in the Research Work Order. These include; building the simulation system, designing the field experiments, and conducting and evaluating a pilot validation experiment over the next 12 months.

We are seeking additional funding of $114,000 to fully fund the objectives outlined in this proposal. This funding could be added to the existing Research Work Order in FY05 as indicated in Appendix A or in increments of $57,000 in FY05 and $57,000 in FY06 through an amendment to the Research Work Order. This additional funding will permit us to conduct comprehensive field experiments, and to complete the synthesis of abundance estimation methods, methods for estimating diversity and proportion area occupied, protocol development, and cost benefit analyses described in the proposal.

Out year plans:

A final report of this research will be provided in December 2007 as described in the Research Work Order. The report will address all objectives outlined in the original proposal subject to the availability of additional funding. Current funding will permit us to conduct 2 – 3 additional field experiments using local volunteers between now and July 2005 and to partially address the species diversity and proportion area occupied objectives outlined in the Research Work Order. Full funding will permit us to fully address the species diversity and PAO objectives, and to conduct additional field experiments in 2005 and 2006 using observers from Patuxent Wildlife Research Center, the National Park Service, and the U.S. Forest Service.